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TECHNICAL REPORT
NATICK/TR-96/033

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EVALUATION OF FLAME-RESISTANT BATTINGS

By
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July 1996

FINAL REPORT
December 1993 - May 1995

U.S. ARMY SOLDIER SYSTEMS COMMAND
NATICK RESEARCH, DEVELOPMENT AND ENGINEERING CENTER
NATICK, MASSACHUSETTS 01760-5019
SURVIVABILITY DIRECTORATE

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE July 1996

3. REPORT TYPE AND DATES COVERED FINAL Dec 1993 - May 1995

4. TITLE AND SUBTITLE
Evaluation of Flame-Resistant Battings

5. FUNDING NUMBERS
PR AH98/6.2

6. AUTHOR(S)
Margaret A. Auerbach

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U.S. Army Soldier Systems Command
Natick RD&E Center
ATTN: SSCNC-IR
Natick, MA 01760-5019

8. PERFORMING ORGANIZATION REPORT NUMBER
NATICK/TR-96/033

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

This report summarizes the performance of several flame-resistant (FR) insulative battings and compares the data to the current needled Nomex batting (MIL-B-81813) which is currently being used in the air crewman and combat vehicle crewman cold weather clothing systems. The intent of the effort was to find a batting which would be more thermally effficient, preferably lighter in weight, provide better FR protection, compressional recovery, wet loft retention and water-repellent capabilities. Battings that were commercially available,as well as developmental battings, were evaluated under this program. Two battings were identified which merit further investigation: a P84 (polymide)/polyester blend developed under an army contract and a Curlon/Polyester blend developed under a Navy contract.

14. SUBJECT TERMS
THERMAL INSULATION, FLAME RESISTANCE, COLD WEATHER CLOTHING, THERMAL EFFICIENCY, STAPLE FIBRES, BATTING MATERIALS, HIGH EFFICIENCY, LIGHTWEIGHT, EVALUATION

15. NUMBER OF PAGES 55

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	SAR

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PREFACE

This report summarizes the performance of flame-resistant(FR) insulative battings evaluated under the Flame Resistant High Efficiency Thermal Insulation portion of the Material for Integrated Protection program (IL16278AH98AAA00).

The goal of the program was to develop a thermally efficient FR batting to replace the needled Nomex batting currently used in the Aircrewman and Combat Vehicle Crewman Cold Weather Clothing Systems.

A contract was awarded under this program to Albany International Research Co. Mansfield, Ma., to develop a flame resistant, high efficient thermal insulation (DAAK60-92-C-0035)[1], based on the technology developed under a previous development effort in which a synthetic (polyester) staple cut fiber was engineered to resemble down.[2,3,4] The intent was to build on the same concept used in Primaloft™, but make the resulting batting FR. Several other battings developed for the airline industry and two battings developed for the Navy under Contract N622C9-91-C-0220 were also evaluated under this program.[5,6]

The test data and evaluation done on these insulations will be discussed in this report.

EVALAUATION OF FLAME-RESISTANT BATTINGS

Background

The U.S. Army currently has requirements for flame-resistant (FR) batting materials in both the aircrewman and combat vehicle crewman clothing systems. The batting used in these clothing systems is a needled Nomex™ or Kynol™ (MIL-B-81813: Batting, Aramid or Novoid Fiber, Quilted[7])which is not thermally efficient on a weight basis. NOTE: MIL-B-81813 can be made of Nomex or Kynol but is typically made of Nomex; therefore, throughout this report MIL-B-81813 will be referred to as the standard (std) Nomex or Nomex batting.

It is speculated that when this needled Nomex batting was adopted, it was the best (and possibly the only) candidate that could provide the FR protection required in the clothing systems mentioned. Nomex, which was introduced to the trade in 1961 as an experimental fiber under the code HT-1[8], was the first aramid fiber commercialized by Du Pont in 1967.[9] The earliest date associated with MIL-B-81813 is 1971 (this specification supercedes Purchase Description AS 1822 dated 16 Sept 1968 and the original preparer of this specification was the Navy).[7] Although this specification does not include FR requirements, the end item descriptions of the Jacket, Cold Weather, High Temperature Resistant (MIL-J-43924) is intended to "provide ground combat vehicle crewman and flight crewman with added protection from flash fires and cold weather".[10] The coverall liner which also uses the Nomex batting provides "additional flame protection when the liner is worn with the coverall".[11] The CVC requirement states the flame resistance be state-of-the-art.[12]

It is believed the reason the specification does not provide any FR requirement is because Nomex and Kynol are inherently FR and the finished batting is made of fiber only, with no added resins or material thus making the batting inherently FR.

Because there are no FR requirements, all candidate replacements must be equal to or exceed the performance criteria of the Nomex batting. The ultimate goal would be to develop a batting which has the following improvements over the currently used Nomex batting: lighter in weight, more thermally efficient, better FR protection, better compressional recovery and wet loft retention and reduced water absorption capabilities.

Over the years, numerous insulations claiming to be FR have been evaluated as possible alternatives to the Nomex batting. These battings either did not provide the same level of FR protection; did not provide better or equivalent thermal and /or performance properties as the std Nomex batting and/or were not cost effective.[13,14,15] Many of the FR polyester battings evaluated provided better protection than untreated polyester battings because they did not melt and drip. However, they did not provide sufficient FR protection from flame heat. When exposed to flame heat, the batting would rapidly melt and fuse

over a length exceeding our requirements.[1,14]

The current program to evaluate suitable FR insulation candidates to replace the standard Nomex batting evolved for several reasons. First, FR requirements placed on the airline industry by the Federal Aviation Administration (FAA) in recent years[16,17,18] have made more FR insulations available on the commercial market. Although many of these insulations are currently used in aircraft, they may have potential clothing or equipment applications, or could be reengineered to meet these required properties. Secondly, the technology exists to make a highly thermal efficient synthetic batting. Last and most important, there is an increased desire for FR protection in clothing systems under development.

In the past, aircrewman and combat vehicle crewman needed FR protection due to the large number of injuries or deaths caused by burns not only in combat but in non-combat post crash fires. There is no dispute that aircrew and tankers are at a higher risk of being hit in combat situations by artillery, mine or flame weapons and need more time to exit their burning vehicles. However, the increasing number of fire and incendiary weapons on the battlefield has made FR protection desired for the ground soldier.

In fact, after ballistics, flame is ranked as the greatest threat on the current battlefield and is projected to remain so until the year 2000, according to threat analysts at the Foreign Science and Technology Center.[12] This is not so surprising if one realizes that flame and incendiary weapons are 4 to 5 times more effective than high explosives or fragmentation, incapacitate people for longer periods of time and cause injuries with lasting psychological impacts.

Therefore, this program was undertaken in an effort to improve the flame protection currently provided to the combat vehicle crewman and provide a satisfactory level of protection at a reasonable cost to the ground soldier.

Materials:

The FR insulation materials evaluated in this program were obtained from a variety of sources. Details of each insulation follow:

Nomex:

As mentioned, a needled Nomex batting conforming to MIL-B-81813 was evaluated as a control sample. This batting weighs 3.8 - 4.8 oz/sq yd and is made with a nominal 2 denier, 1-1/2" - 2" length aramid fiber. The sample tested was received quilted between two layers of Nomex fabric as specified in MIL-B-81813 and conforming to MIL-J-43924. Data on the Nomex batting alone, was obtained by removing the quilting. Unquilted Nomex data was available from previous testing. Data on both the unquilted Nomex batting and the Nomex batting with the quilting removed (Nomex (QR)) will be presented.

P84/Polyester blend:

A batting consisting of 60% 1.5 denier P84 (polyimide) with water repellent (WR) finish, 22% 0.55 denier P84 with WR finish and 18% 4.0 denier polyester binder fiber - Hoechst Celanese Type K54 - was developed under a government contract (DAAK60-92-C-0035).[1] This batting was based on the principles applied from previous development efforts with Albany International Research Co.[2,3,4]

EDF/Curlon Blends:

Two EDF/Curlon blends developed under a Navy contract (BAA N62269-91-C-0220) with Auburn University were evaluated.[5] One batting was a blend of 75% Curlon/25% Polyester. The Curlon fiber used was 1.5 denier to start - SP15 (special precursor 15 dtex) and ended up being approximately 10 microns after processing. The Curlon fibers were 1.5 inch in length.[19] A 5.0 denier crimped bi-component polyester was used as a binder fiber. The fibers were air laid on a rando webber (no cross lapping). No WR finish was applied, although a fluorocarbon WR finish is currently available for use on Curlon blends.[19] The second batting was a blend of 40% EDF Carbon, 40% 0.7 denier 2" polyester staple and 20% 2 denier Cellbond sSheath cCore bi-component polyester.

The 75/25 Curlon/Polyester blend was received quilted to a Nomex pajama check conforming to MIL-J-43924; therefore, the quilting was removed to obtain data on the batting alone. The 40/40/20 (60% Polyester 40% EDF) blend was received both unquilted and quilted to a FR cotton which is 100% cotton plain weave/proban treated cotton (Navy fabric).

Note: EDF is an experimental carbon (black fiber) developed by Dow Chemical Co. Dow Chemical licensed this technology to RK Carbon Fibers, Inc. and EDF is no longer available as a result of proprietary rights. RK changed the name of EDF to Curlon. According to Auburn University, "there is no difference in performance characteristics between batts made of Curlon and batts made of EDF when density, weight, and thickness are kept constant".[5] According to Dr. Novis Smith, president of R.K. Carbon Fiber, Inc. - Curlon is made up of 70% non-conducting carbon and 30% nitrogen. It is a heat-treated, cross linked thermoset fiber containing carbon and nitrogen.[19]

Fiberglass Battings:

Two fiberglass battings developed for the airline industry were received from Schuller International. Both battings received - Microlite AA and Acoustic AA - use fiberglass fibers ranging from 0.3-2.0 microns with the average fiber diameter size being 1.0 - 1.2 microns. The samples used a phenolic resin with WR additives. While glass fibers melt around 1200-1300°F, the

phenolic resin is rated at 450°F. A silicon resin version rated at 700°F is available. The Acoustic AA had a Reemay polyester backing on it to aid in sewing. Because these battings were developed for the airline industry, they do provide acoustic properties as well. See Appendix B - for Product Information Sheet.

Additional Battings:

In addition to the battings listed above, several other commercial battings were evaluated in the initial phases of the program. Two samples of modacrylic battings quilted in a 2.5" and 4" square pattern to a FR cotton were received from Westex Inc. (Chicago, Illinois). The data on this material can be found in Table A-7. A 72% Curlon/28% Polyester (binder fiber) batting was received from RK Carbon Fibers Inc. for evaluation for glove liners. Three battings - Pyroloft C, Pryroloft CA - using a high temperature binder and Pyroloft A (Aerobat 5.5 dtex) battings were received from A.L. International L.P. (a merger between Albany International Research Co. and Lenzing AG. Austria). The data generated on these materials is provided in Appendix C. However, not all tests were run on these samples due to limited availability of material and/or insufficient interest in pursuing these battings further.

Test Methods

The following test methods were used to characterize the thermal and mechanical properties of the materials.

Thickness Measurements

Batting thicknesses were measured on panels using a calibrated Measure-Matic Thickness Gauge under a pressure of 0.002 pounds per square inch (psi).

Thermal Properties

Thermal Properties of the battings were evaluated using two test instruments - a guarded hot plate and a heat flow meter or Rapid "K" Thermal Conductivity Instrument.

Guarded Hot Plate Testing

The guarded hot plate measures the thermal resistance (clo value) of an uncompressed sample lying on a heated plate surrounded by a cooler atmosphere. Depending on the test conditions or chamber, a wind speed may be introduced. The thermal resistance (reported in units of clo) was determined in accordance with ASTM D1518, Standard Test Method for Thermal Transmittance of Textile Materials, except that the chamber air velocity was not controlled to less than 0.1 m/sec. (it was

maintained at 3-4 m/sec). The surface temperature of the guarded hot plate was maintained at 92°F ± 0.5°F (33.3°C) and the air at 50°F ± 0.5°F (10°C) with a 50% relative humidity. The intrinsic clo is the unit of insulation reported. The intrinsic clo of the material is obtained by subtracting the thermal resistance of the plate and the boundary air layer from the total clo measurement.

Rapid K or Heat Flow Meter Testing

The heat flow meter measures the thermal conductivity of a sample sandwiched between and in contact with a heated upper plate and a cooler (refrigerated) lower plate. The distance between the upper and lower plates can be adjusted to determine the thermal properties of the sample at varying thicknesses or bulk densities. These tests were conducted according to ASTM C-518, Standard Test Method for Steady-State Heat Flux Measurements and Thermal Transmission Properties by Means of the Heat Flow Meter Apparatus. The heated upper plate was maintained at 95°F (35.0°C) and the cooled lower plate was maintained at 55°F (12.8°C). The distance between the plate was adjusted to determine the thermal conductivity of the sample compressed to density levels of 0.5 lb/ft^3, 1.0 lb/ft^3, 1.5 lb/ft^3 and 2.0 lb/ft^3 (where applicable).

The differences between the two test methods are 1) in the guarded hot plate the heat flows from the plate up through the sample (convection involved) while in the heat flow meter test the heat is flowing from the upper plate down into the sample (eliminating convection) - and 2) in the heat flow meter test, the plate is in direct contact with the sample eliminating the insulating air layer over the sample which is present in guarded hot plate testing.

Flammability Testing

Flammability testing was performed using Fed Std 191A Test Method 5903.1 Flame Resistance of Cloth, Vertical. As mentioned no flame test method is indicated in MIL-B-81813. However, this is the test method used over the years for evaluating substitute materials. All battings were tested alone (without cover fabrics).

Compression Properties

Compression properties were determined on an automated instron using a compression-loaded cell. Gauge lengths for each sample differed and were measured at the "touch density" of 0.002 psi and 0.01 psi. The requirement of the standard MIL-B-81813 is reported at 0.01 psi. The touch density of 0.002 psi is used for standard polyester battings MIL-B-41826 Batting, Synthetic Fibers, Polyester (Unquilted and Quilted). According to a study done on varying pressures exerted on down, lighter pressures

(0.002 psi) exhibit more pronounced differences in the filling power of down and feather materials than higher pressures (0.01 psi). However, the difference between 0.002 and 0.01 did not cause a significant change in the ranking of down and feather materials.[21] Therefore, data will be reported at 0.01 psi in accordance with MIL-B-81813.

The test procedure as specified in MIL-B-81813 requires a 20 square inch sample of the material to be subjected to 0.01 psi (0.2 lbs) and the initial thickness measured. Then the pressure is increased to 5 psi (100 lbs.) and held at that pressure for one minute. (Three psi is the maximum pressure exerted on a sleeping bag (shoulder, buttocks area) - when a person is lying down).[22] The pressure is then removed and the batting is allowed to relax 5 minutes. The thickness is then measured at 0.01 psi (thickness after compression). The compression recovery is defined as follows:

$$\frac{\text{Thickness after compression}}{\text{Initial thickness}} \times 100$$

The compressibility (the difference in volume or height before and after compression) of the sample is defined as:

$$\frac{\text{Initial Thickness - Thickness after comp.}}{\text{Initial thickness}} \times 100$$

The resilience (the difference between the recovered volume and the compressed volume) is defined as:

$$\frac{\text{Thickness after comp. - Compressed Thickness}}{\text{Initial thickness - Compressed thickness}} \times 100$$

Data was obtained from an average of 6 samples unless otherwise specified.

Absorptive Capacity and Wet Loft Retention

The absorptive capacity and wet loft retention were determined using a variation of ASTM D1117, which was adapted by Albany International under a previous contract.[2]

The test requires cutting six - 2" x 4" samples, weighing them and measuring their thickness. The samples are then placed in a stainless steel vegetable steamer and immersed in approximately 6" of water for a specified time (in this case 20 minutes). After 20 minutes, the samples were left in the strainer and allowed to drain sideways for 1 minute. They were then tapped against the edge of a sink 10 times, removed from the strainer, weighed and the thickness measured.

The thickness was measured using an anvil and presser foot at 0.1 psi (0.1 psi was the lowest pressure possible based on the anvil and presser foot available). Absorptive Capacity is defined as

$$\frac{\text{Wet Weight}}{\text{Dry Weight}} \times 100$$

Loft retention is defined as

$$\frac{\text{Wet Thickness}}{\text{Dry Thickness}} \times 100$$

Quilted Battings

Insulating materials were placed between a nylon-taffeta fabric (MIL-C-21852, Type III) and quilted with 6 inch channels. (Except where samples were received already quilted in another pattern as indicated). Samples were cut to 26 sq. inches to accommodate the guarded hot plate.

Laundering

Quilted panels were laundered according to Method 5556.1: FED STD-191 Cotton Laundering Schedule in accordance with the laundering procedure specified in MIL-B-41826G Batting, Synthetic Fibers, Polyester (Unquilted and Quilted) as outlined below:

Laundering Procedure

Three 26-by 26-inch squares of batting shall be cut from the sample unit. The specimens shall be prepared as specified in Method 5556.1 of FED-STD-191 except that the Type III cloth of MIL-C-21852 shall be allowed as an alternate to MIL-C-332, Cloth, Balloon, Cotton batting cover fabric. The prepared specimens shall be marked for dimensional stability as specified for woven fabrics on one of the sewn-on cover cloths to each prepared specimen. The three prepared and marked specimens shall then be subjected to three cycles of Method 5556.1: Cotton Procedure, except that the maximum load shall be 10 pounds consisting of a 5 pound maximum load of batting specimens and utilizing a medium weight cotton ballast cloth. The drying temperature shall be 130° to 150°F, and the specimens shall not be moistened or pressed after drying. As required in Test Method 5556.1 Section 3.2 an additional wash cycle was performed without adding a detergent or sour. The laundered specimens were used to determine dimensional stability, launderability, thickness, and compressional recovery after laundering.

Shrinkage and Launderability Rating

The laundered samples were measured for dimensional change. The percent changes in both the machine (length) and cross machine (width) directions were calculated for each specimen. A 5.0 (max.) percent change was acceptable in accordance with MIL-B-41826.

After measuring dimensional stability, the batting was removed from the quilted composite and placed flat on a black background under an overhead light. The samples were visually examined and compared to the Photographic Rating Standards for Fiberfill Durability ASTM D4770 (only the photographic standards portion of this test was used). The averaged rating from the three samples viewed must be a minimum of "4.0" to achieve a satisfactory rating. No rating can differ among the three specimens by more than 1.0 or the sample will be rated "unsatisfactory".

Results and Discussion

All data can be found in Tables A-1 - A-7 in Appendix A.

A. Thermal Properties - Batting Samples (Unquilted)

MIL-B-81813 Batting, Aramid or Novoid Fiber, Quilted, uses a batting filler which is needled for compactness and cohesion and does not provide very good thermal properties on a weight basis (clo/oz/sq yd). In fact, all of the samples tested exhibited better thermal efficiencies (clo/oz/sq yd) and higher intrinsic clo values than the std Nomex batting. See Table A-1.

1. Guarded Hot Plate Testing

The Guarded Hot Plate data and corresponding physical properties of the battings evaluated can be found in Table A-1. Note: Data is available on the Nomex batting before quilting and with the quilting removed (designated QR). While the unquilted and Nomex QR samples exhibit some variations in the bulk density and weight (oz/sq.yd.) measurements after laundering, most of the data does not exhibit significant differences. Data on the 75% Curlon/25% Polyester sample was obtained after removing the quilting (designated QR). Unquilted batting was not available as this was developed under a Navy contract and delivered quilted. Because the 75% Curlon/25% Polyester blend is over the maximum weight of 4.0 oz/sq yd all battings were normalized to 4.0 oz/yd sq or oz/sq yd for comparison. When all the battings evaluated were normalized to 4.0 oz/sq yd, the P84/polyester blend is roughly three times more efficient than the current std Nomex batting before laundering (216% QR, 227% unquilted) and two and a half times more efficient (150% QR, 133%-unquilted)than the std. Nomex batting after laundering despite the fact that it loses 44% of its thickness and experiences a 33% loss in clo value. Initially both the 60% Polyester/40% EDF blend and the 75% Curlon/25% Polyester

battings are roughly 2 times more efficient (111% - 104%) than the std. Nomex batting before laundering. The 60% Polyester/40% EDF batting loses considerable loft in washing resulting in a 56% loss in thickness and a 58% loss in thermal resistance. Therefore, while the 60 Poly/40 EDF batting exhibits a comparable clo/oz/sq yd as the std Nomex batting after laundering it does not exhibit any improvement over the current batting. The 75% Curlon/25% Polyester batting, however, is more efficient than the std. Nomex batting (1.84 - 75/25 Curlon/Polyester clo/4.0 oz/sq yd vs. 1.04 clo/4.0 oz/sq yd) after laundering. (See Fig. 1a and 1b)

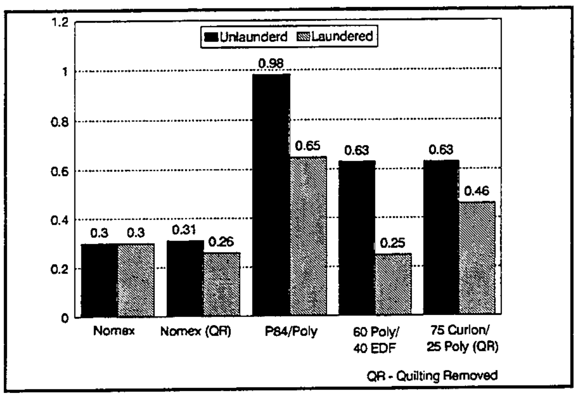


Figure 1a. Clo/Oz/Sq Yd

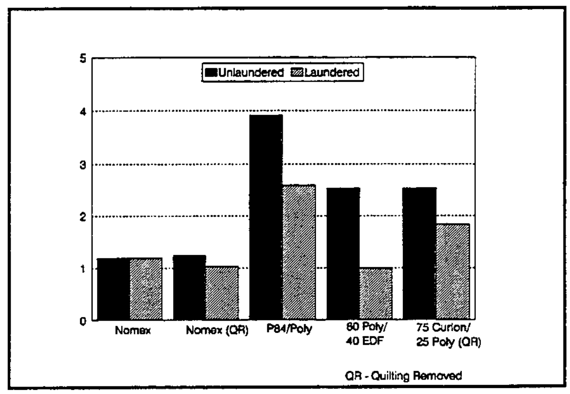


Figure 1b. Clo/ 4.0 Oz/Sq Yd

A difference of 0.5 clo is perceived by the wearer.[23] Therefore, while the P84/Poly blend exhibits the best thermal properties of the battings tested, the 75% Curlon/25% Polyester batting would also exhibit a noticeable improvement in warmth over the std Nomex batting both before and after laundering.

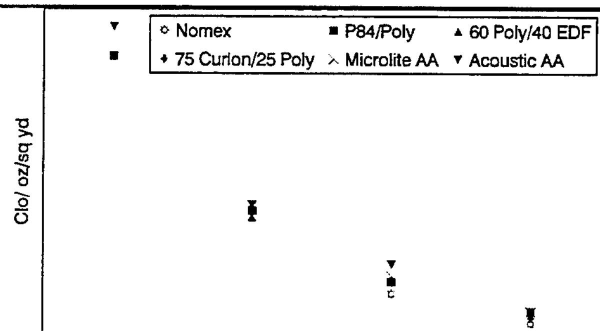
Guarded Hot Plate Testing was not conducted on the fiberglass samples, as they most likely would not be used in a clothing application due to skin irritations and unsatisfactory durability in wear. (In the late 1940's, fiberglass battings were tested and found to be unsuitable in military uniforms due to poor durability in wear. [24,25])

2. <u>Rapid K Testing</u>

The Rapid K test data can be found in Table A-2. Rapid K testing was only conducted on the std Nomex batting after the quilting was removed (QR).

Four of the six standard Nomex batting samples tested demonstrated original densities below or equal to 1.5. Therefore,

although the average original density was 1.52 and the clo 1.17, at a density of 1.5 lb/cu ft the four samples had an average clo value of 1.16. At a bulk density of 1.5 lb/cu ft, the 75% Curlon /25% Polyester and the Microlite AA (Fiberglass) samples appear to exhibit the best clo values and maintain higher thicknesses when compressed. However, these two battings also happen to be heavier (approximately 7.0 oz/sq yd). In actuality all of the battings provide comparable thermal efficiencies (clo/oz/sq yd) at 1.5 lb/cu ft and 2.0 lb/cu ft to the std Nomex. (See Fig. 2)



	0.5 lb/cu ft	1.0 lb/cu ft	1.5 lb/cu ft	2.0 lb/cu ft
Nomex			0.27	0.22
P84/Poly	0.67	0.41	0.29	0.24
60 Poly/40 EDF		0.40	0.29	0.24
75 Curlon/25 Poly		0.41	0.29	0.23
Microlite AA		0.42	0.30	0.24
Acoustic AA	0.72	0.42	0.32	0.24

Figure 2. Clo/Oz/Sq Yd vs. Density

It is well documented that lower density batts provide higher thermal properties which is what makes down thermally efficient, so it comes as no surprise that the P84/Poly blend and Acoustic AA (fiberglass) battings exhibit the highest clo values when uncompressed. These battings have the advantage of having densities lower than 0.5 lb/cu ft. At 0.5 lb/cu ft. these battings demonstrate comparable thermal efficiencies (clo/oz/sq yd) to down and slightly better thermal efficiencies when compared to the std. polyester battings. (See Fig. 3) Note: The P84/Poly blend has a slightly higher thermal efficiency than Primaloft (the batting after which it was modelled - 0.67 vs 0.65). The Acoustic AA batting exhibits the same thermal efficiency as down. Based on all of these findings, it becomes apparent that the bulk density will play an important role in choosing the best candidate to replace the std Nomex batting. An important issue that must be resolved is what bulk is acceptable to the end user and where do the tradeoffs between bulk and density come in.

In summary, the P84/Poly blend and Acoustic AA batts exhibit the best thermal properties in the group evaluated. After

laundering both the P84/Poly blend and the 75%/Curlon/25% Poly blend, exhibit better thermal efficiencies than the std Nomex batting. These increased thermal resistances or clo values are a result of lower bulk densities. Once the battings are compressed to 1.0 lb/cu ft, or higher, all the battings tested provide equivalent thermal efficiencies (clo/oz/sq yd). The 60% Poly/40% EDF sample exhibits a considerable loss of thickness 56% and thermal resistance 58% after laundering. Retention of insulation and physical properties of the batting after laundering is important since this will effect the long term performance of an item. Therefore, while the 60% Poly/40% EDF sample exhibits better clo values than the std. Nomex batting before laundering it offers no significant advantage over the std Nomex batting after laundering and would not be a suitable replacement based on changes in it's physical characteristics (thickness, bulk density) after laundering.

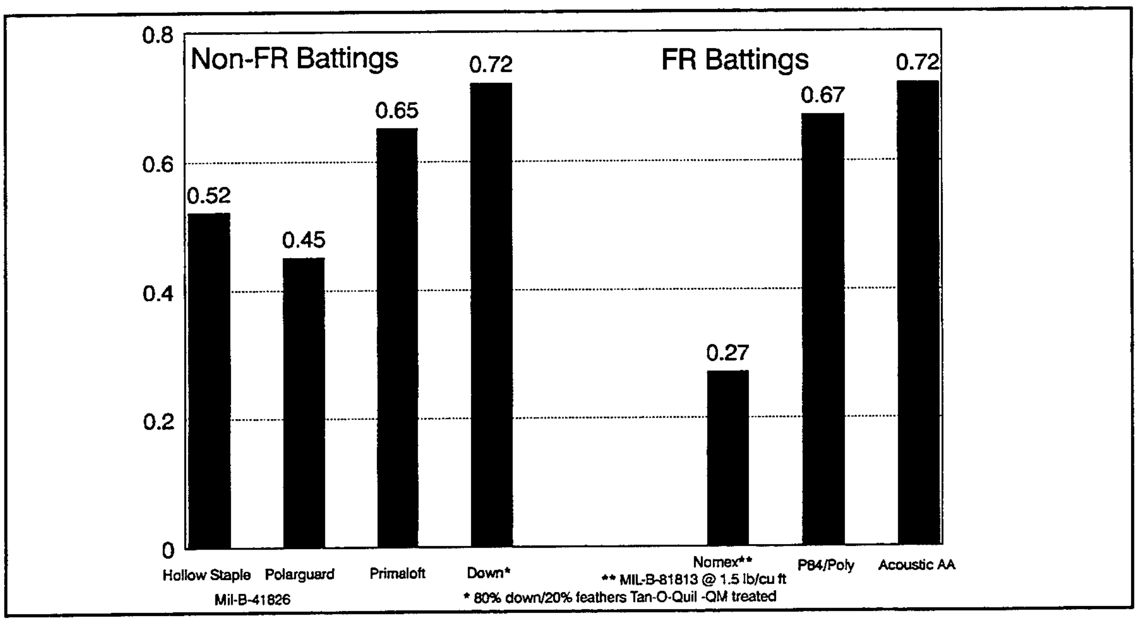


Figure 3. Clo/Oz/Sq Yd @ 0.5 lb/cu ft

Flammability Testing

All samples were tested according to Fed Std 191A TM 5903.1 both before and after laundering using no cover fabric. A summary of the test results can be found in Table A-3. Individual specimen tests can be found in Appendix D. The method for measuring the char length as defined in the test method is the lengthwise tear made through the charred area and is indicated in Table A-3 under "char length". However, this test method was designed for testing fabrics and it was found that the batting samples tested, could

burn beyond the "char length" because the charred area did not tear or break open (it's not brittle) when the weight is applied. Therefore, the "affected area" designates the portion of the batting affected by the flame. Technically, the batting may still offer some protection in the affected area and it is the "char length" measurement which will have the greatest effect on the overall protection provided by the batting.

In reviewing all the data, the 75% Curlon/25% Poly sample provides the best flammability properties of the candidates evaluated both before and after laundering. This batting does not burn and exhibits even better flammability characteristics than the std. Nomex batting.

With the exception of the P84/Poly blend, all of the other samples evaluated provided acceptable flammability requirements before laundering. The 60 Poly/40 EDF sample and P84/Poly samples demonstrate unsatisfactory flammability characteristics after laundering.

It should be noted that one of the initial five unlaundered P84/Poly blend samples demonstrated an after flame of 11.5 secs. far exceeding the 0 sec after flame requirement. Even though five additional samples were tested and passed with 0 after flame, this data causes some concern about the flammability characteristics of this material, particularly in light of the unsatisfactory after flames experienced by this batting after laundering. In fact, both the P84/poly and Poly/EDF blends demonstrated long after flames after laundering.

Albany International Research Co. attributed the long after flames of the P84/Poly blend after laundering to "incomplete soap removal" contending that additional rinsing removed the detergent and improved the flammability. However, upon reading the report, the additional rinsing done on the battings was done with the cover fabric removed and the "repeated additional rinsing of the open, unquilted insulator samples tended to distort them, and it seemed, remove only trace amounts of detergent".[1]

Based on the flammability test results obtained on the P84/Poly and Poly/EDF blends, it appears the increased densities were contributing factors in the diminished flammability properties of these battings after laundering. In fact, the P84/Poly blend experiences a 44% decrease in thickness and a 77% increase in bulk density and the Poly/EDF blend experiences a 56% decrease in thickness and a 140% increase in bulk density. (See Table A-1). If in fact this is true, it would explain why the Poly/EDF samples, which experience the greatest change (in terms of thickness & density) in laundering exhibits the worst flammability characteristics after laundering.

The Poly/EDF blend demonstrates increased afterglows and

noticeably worse char length measurements after laundering. In fact, many of the 12-inch samples tested were completely consumed. An interesting phenomenon occurred during testing of the laundered Poly/EDF blend samples. In three of the eleven samples tested (one set of data was eliminated due to inaccurate time data) the flame appeared to go out, and an after glow was present for a few seconds, then the sample reignited. This may have been a result of the poor blending and opening of the polyester fibers in the batt or may have been a combined effect of poor blending and density loss.

According to studies done on the thermal response of fabrics, maintaining air gaps between fabric layers is important in keeping the materials away from the skin and the presence of air gaps helps aid in resistance to heat transfer which, in turn, results in longer periods of heating and less burn injury to the wearer.[20] Therefore, lower density battings would not only slow down the penetration of the flame through the sample, but would aid in providing less heat transfer through the sample providing greater protection to the wearer. In the battings tested, the air gaps within the batting may also aid in insulating the FR (P84/EDF) fibers from the non-FR fibers (polyester). Because of the increased densities of the battings after laundering, synergistic effects may be occurring between the FR and non-FR fibers as a result of loosing this "insulation". This may account for the sporadic results obtained on the laundered P84/Poly samples (see Appendix III) and may account for the improvement in flammability properties obtained by Albany International Research Co. as a result of soaking the unquilted batting which reportedly "distorted" the battings.

Further work is needed to explore the flammability/density FR/non-FR fiber issues.

Considerable time has been spent trying to determine an appropriate FR test method to use in evaluating batting materials as none exist. In light of the new directive by Secretary of Defense William Perry to go to performance based specifications, it may be more appropriate to test these batting materials with cover fabrics, with no raw edges exposed (as in a garment). This test is referred to as a Modified 5903 and is a NFPA Test Method (NFPA 1993 Support Functions Protective Garments for Hazardous Chemical Operations). It may also be more appropriate to conduct TPP (Thermal Protective Performance) tests. There are two types of TPP testing. One is referred to as "Conductive TPP" this measures the heat energy required to pass through the sample and reach a standard threshold of pain - ASTM F/1060 Standard Test Method for TPP of Materials for Protective Clothing for Hot Surface Contact. Here the sample is put on a heated plate and the amount of heat transmitted by the material is compared to human tissue tolerance. Temperature response of a calorimeter reacts to the heat like human skin giving the threshold of pain in seconds (Time-to-pain). (The

amount of heat transmitted by the material is compared to human tissue tolerance). The other test is referred to as the open flame TPP (NFPA Std. 1971, Protective Clothing for Structural Firefighting based on ASTM Standard D 4108, TPP of Materials for Clothing, Open Flame Method); here the heat flow is adjusted to 2 cal/cm^2/sec and heat from two Meker burners impinge the sample. The temperature rise on the opposite side of the sample is recorded by a calorimeter to determine the total amount of heat energy needed to produce a second degree burn on human tissue. This test method uses a convective and radiant thermal flux and represents a POL (petroleum oil and lubricant) fire .[26] (A second-degree burn usually will heal naturally, while a third-degree burn would require skin grafts).[27]

While test methods exist for all the tests mentioned, and have been used in recent screenings - JSLIST, AUIB, Mounted Crewman, Glove, Aircrew Cold Weather - no universal standard method for testing fire resistance/protection of textiles exist. In addition, smoke presents a greater hazard than heat, and toxicity testing should be incorporated into material screening tests. While it is documented that the Nomex aircrewman jacket provides the soldier with "valuable" time to egress from burning wreckage[28] the thermal/flame hazard needs to be quantified and flame protection levels established to determine what protection is needed and what the current systems provide.[12]

Compression Properties

The compression properties of the samples evaluated can be found in Table A-4.

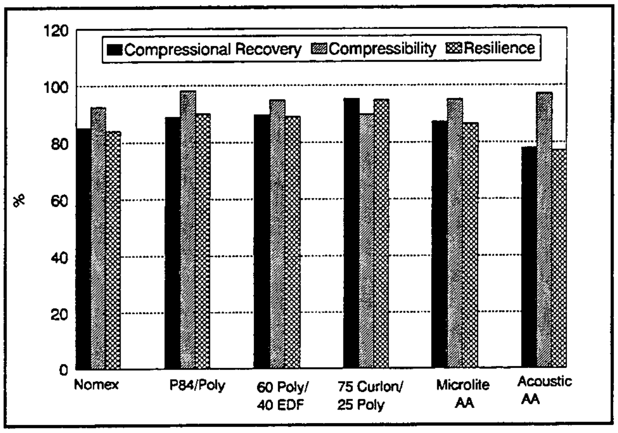
All of the samples exhibit compressional recovery that meet the minimum requirement of MIL-B-81813 which is 75%. The 75 Curlon/25 poly sample demonstrates the highest compressional recovery of the samples tested (95.3%). The Acoustic AA sample exhibits the lowest compressional recovery 77.8%.

Resilience measures the materials ability to store energy upon compression and release it when the stress is removed or the work a material is capable of doing in returning to its original size and shape following release from applied compression.[21] All the samples tested (except the Acoustic AA sample) demonstrate higher resilience than the Nomex sample before laundering. The 60 Poly/40 EDF sample demonstrates a lower resilience than the Nomex batting after laundering. The 75/25 Curlon/Poly sample demonstrates the highest resilience both before and after laundering, followed by the P84/Poly blend.

Compressibility is the difference in volume before and after compression, or the ability of the sample to compress.[21] The P84/Poly sample exhibits the highest compressibility while the 75% Curlon/25% Poly sample exhibits the lowest compressibility.

On one hand, the 75/25 Curlon/Poly samples would provide greatest warmth because it doesn't compress as easily as other battings but would be bulkier and take up more room.

Overall, all samples meet the compressional recovery requirement of MIL-B-81813, and demonstrate good compression properties.(see Figs. 4 and 5)



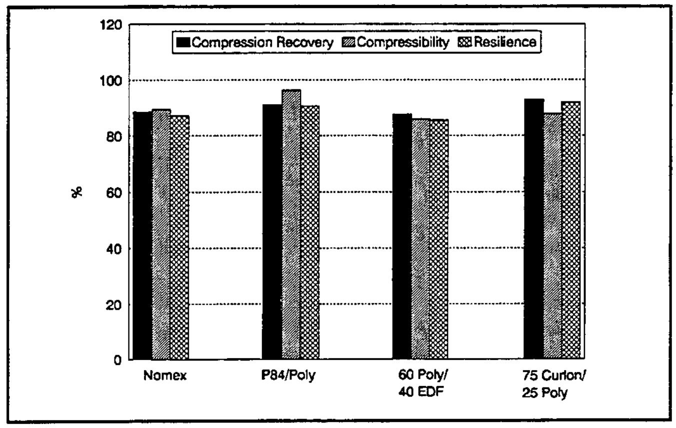


Figure 4. Compression Properties (Unlaundered)

Figure 5. Compression Properties (Laundered)

Water Absorptive Capacity and Wet Loft Retention

Absorptive capacity and wet loft retention data can be found in Table A-5.

The water repellency characteristics of the insulation materials evaluated vary depending on whether they were water repellent (WR) treated or not. The P84/Poly, Microlite AA and Acoustic AA samples were all WR treated and demonstrate relatively low water absorption after 20 minutes of immersion. The P84/Poly sample exhibits slightly higher water absorption rates after laundering, however, it still exhibits good water repellency characteristics.

The Nomex, 60 Poly/40 EDF and 75 Curlon/25 Poly samples demonstrate excessive water absorption after 20 minute immersions. (None of these samples were WR treated). The 75/25 Curlon/Poly sample absorbs more water after laundering than before. The Nomex sample experiences some improvement after laundering, while the 60

Poly/40 EDF sample exhibits a noticeable improvement in its water absorption capability after laundering. (see Fig 6)

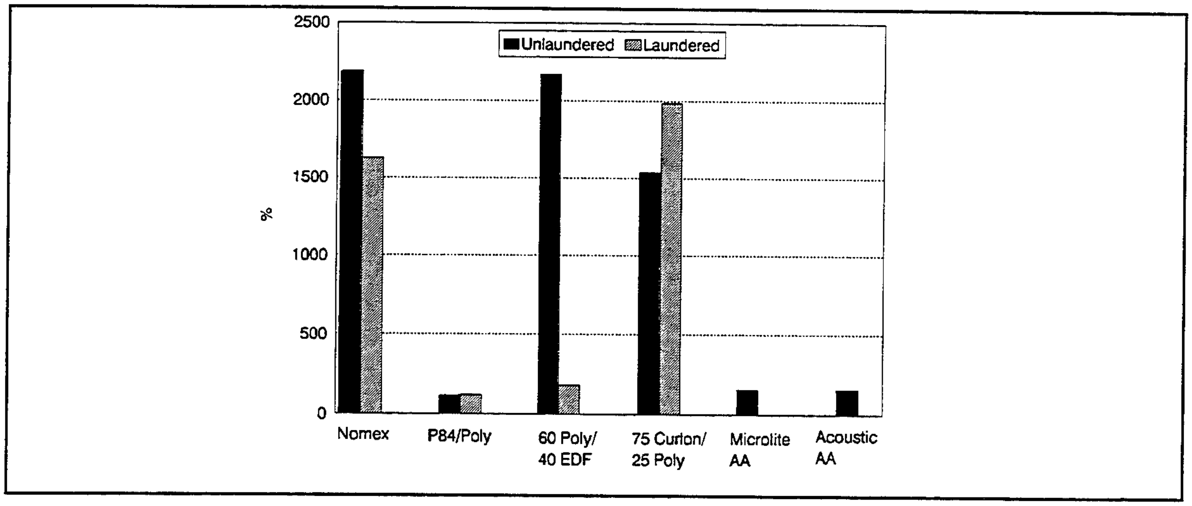


Figure 6. Absorptive Capacity

As discussed earlier, the 60 Poly/ 40 EDF sample exhibits a considerable loss of thickness and loft in laundering. The improvement in water repellency characteristics seen in this sample after laundering may be attributed to several reasons: changes in interfiber spaces or pores as a result of density changes in the batting after laundering; a collapsing of pores due to poor resiliency when wet that would lower the liquid holding capacity of the fibers,[29,30,] or the actual fiber composition and structure. As discussed earlier the sample exhibited poor opening and blending of the fibers and the blend consisted of 40% 0.7 denier (micro denier) polyester fibers. (Microfibers are known to impart water repellency characteristics to fabrics due to a high density of fibers in the fabric and a high surface area).[31] In fact, during testing, the 60/40 Poly/EDF unlaundered samples, did appear to exhibit areas which did not absorb water-mainly those areas where polyester (white microdenier) fibers were clustered, while the EDF areas wetted out turning black, creating uneven thicknesses in the batting, and giving the appearance of "air pockets". In the laundered sample, this phenomenon was not apparent probably due to the decreased thickness of the sample (54%) and the water appeared to be more evenly distributed throughout the sample. The laundered Nomex sample experienced a 36% decrease in thickness, but still exhibited some areas which appeared to absorb no water (similiar to that seen in the unlaundered Poly/EDF samples) which may explain why the sample experiences some improvement in water absorption after laundering. The laundered 75/25 Poly/Curlon sample, on the

other hand, maintained more loft after laundering (14% decrease in thickness) which may have contributed to the increased rate of water absorption after laundering . This data suggests that the thickness change of the battings in laundering also impacts the water absorption properties of the batting materials.

The wet loft retention was measured at 0.1 psi. At this pressure, pronounced differences in the loft retention will not be perceived as well as if measurements were taken at lighter pressures. (see Test Method - Compression Properties) All of the unlaundered and laundered samples demonstrate better wet loft retention than the Nomex sample with the exception of the laundered 75/25 Curlon/Poly sample which demonstrates slightly lower but not noticeably lower wet loft retention than the Nomex sample after laundering (see Fig 7) Visually, the 75/25 sample contained alot of water when wet but appeared to regain it's loft when dry. The P84/Poly, Microlite AA and Acoustic AA samples did not appear to absorb much water, the water appeared to be on the surface of the samples and the samples dried fairly quickly. The Nomex sample absorbed alot of water and took a long time to dry.

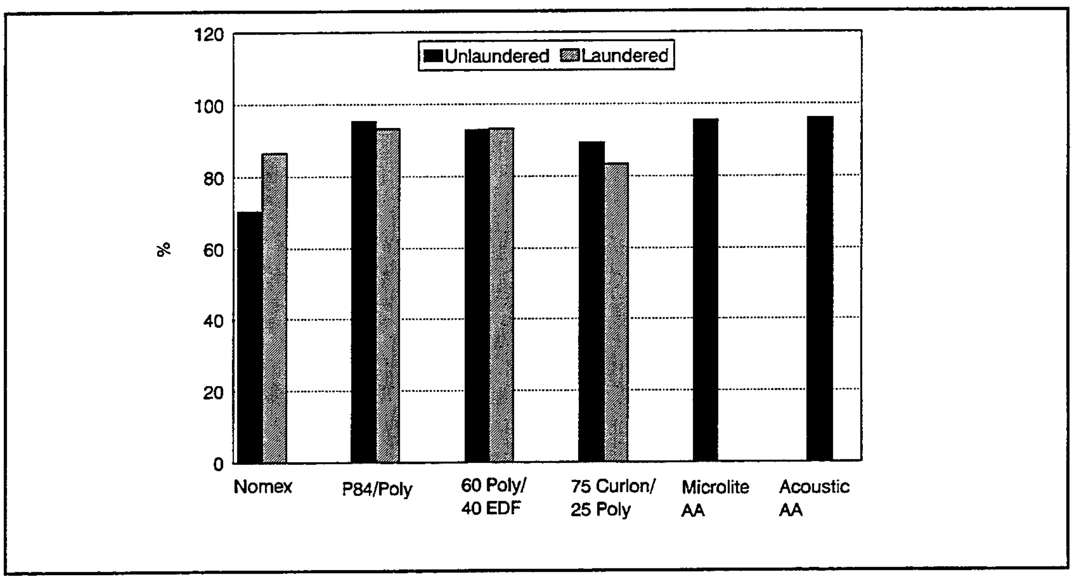


Figure 7. Wet Loft Retention After 20 Minute Immersion

Laundering

Laundering was not conducted on the fiberglass batting samples (Microlite AA and Acoustic AA). These battings were developed for

the airline industry for use in aircrafts and claim high thermal & acoustic properties but have no laundering requirements. It is not known what impact laundering would have on these battings and/or the phenolic resin.

Dimensional stability and laundering durability data can be found in Table A-6. The Nomex, P84/Poly, 60 Poly/40 EDF, and 75 Curlon/25 Poly samples demonstrated satisfactory dimensional stability and good durability to laundering. There is no evidence of fibers roping, or thin and thick spots in the sample after laundering.

The modacrylic samples were received quilted in a square pattern (2.5" and 4") to an FR cotton shell material on one side only. This sample was overedged to a nylon taffeta shell material to determine its durability to laundering. Both the modacrylic samples demonstrated satisfactory shrinkage but unsatisfactory durability in laundering with noticeable thin spots after laundering.

Thermal Resistance Quilted Panels

Batting samples were quilted before laundering (if they were received unquilted) using a 6 inch straight channel quilt and a nylon taffeta shell (see test procedures). Guarded Hot Plate Testing was conducted on the quilted panel before and after laundering. Note: the straight quilted P84/Poly and 60 Poly/40 EDF samples were not tested before laundering due to equipment and time constraints. This data can be found in Table A-7.

The samples demonstrate variations in the shell fabrics and quilting patterns, however, the following observations are made: (see Fig. 8)

a. The 75 Curlon/25 Poly sample exhibits a higher thermal efficiency (62%) than the Nomex sample both of which are dumbbell quilted to a Nomex shell.

b. The P84/Poly sample after laundering, exhibits the best thermal efficiency (clo/oz/sq yd) in the group (115% better than Nomex, 33% better than 75 Curlon/25 Poly blend).

c. The modacrylic battings exhibited a considerable loss in thickness (65% - 66%) and thermal resistance (43 -49%) in laundering. These samples exhibit a 45-50% loss in thermal efficiency (clo/oz/sq yd) in laundering.

d. The 60 Poly/40 EDF and modacrylic battings both quilted to a FR cotton (although quilt patterns differed) exhibited

comparable thermal efficiencies before and after laundering.

e. After laundering, the 60 Poly/40 EDF sample that was channel quilted using a nylon taffeta shell fabric exhibits a better thermal efficiency than the dumbbell quilted sample.

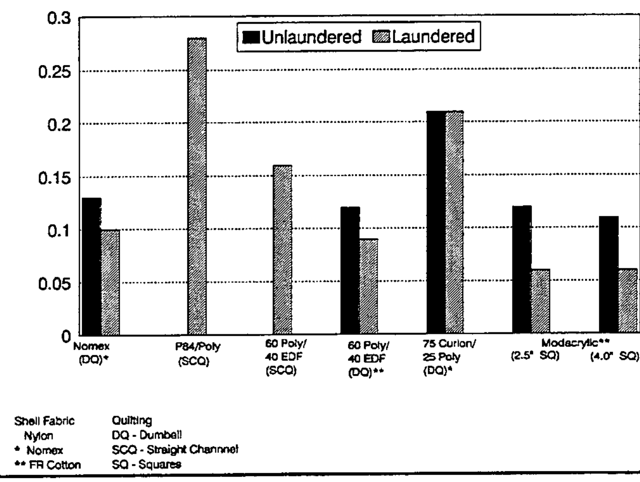


Figure 8. Clo/Oz/Sq Yd (Quilted Panels)

Other Considerations

Although not tested or evaluated in this report, several other issues involving the battings being evaluated may or may not need to be addressed in further development efforts.

The P84/Poly batting exhibited some static problems while testing making it difficult to remove the sample when performing tests. While static may be good in battings because it will repel fibers causing a natural air gap, and thus provide insulation, it may result in problems for fuel handlers etc, where static dissipation is important. The Nomex shell which would be used with the batting does have an anti-static requirement. However, testing the effect, if any, of the static buildup in the insulating materials is needed.

Many of the FR insulations developed for the airline industry claim to have acoustic properties which may benefit the military. The "black fiber" Curlon/EDF may impart some infrared properties to the ensemble or may be capable of reducing thermal signature. Further exploration into these areas may have merit.

Tests involving fiber migration in laundering should also be conducted. Although no fiber migration problems were visible in the samples tested, further work should be done in this area. In the Primaloft program, fiber migration problems did not surface until items were constructed and laundered.[32] Since P84/Poly blend is modelled after Primaloft and uses microdenier fibers, it is possible end items may experience some fiber migration problems. Likewise, the "carbon fiber" has been known to exhibit some fiber migration problems.[33] It should be noted that the Nomex batting currently used exhibited fiber migration problems when constructed into garments for field use. This problem was attributed to loose fiber ends of the Nomex batting material penetrating through the Nomex cover fabric at its interstices resulting in a pilled appearance. It was resolved by reversing the batting construction so the face of the quilted batting was the needled side of the batting and the bobbin thread was changed to natural to make sure the batting was positioned properly in the jacket, so that the loose fiber side of batting was the interliner and faced the wearer. This appeared to sufficiently eliminate the problem.

Conclusions:

Overall, the P84/Poly and 75 Curlon/25 Poly blends appear to be possible candidates to replace the std Nomex batting currently used in the aircrewman and CVC cold weather jackets. While both battings provide better thermal efficiencies than the std Nomex battings, some further development and/or evaluations is needed before they could replace the std Nomex batting.

The P84/Poly sample exhibits good thermal properties before and after laundering, good compressional recovery, good water repellency and good shrinkage and durability to laundering. However, the sample exhibits questionable flammability characteristics before laundering and unsatisfactory flammability characteristics after laundering. More flammability testing needs to be conducted using an end item based test to determine if the sample provides sufficient flammability properties before and after laundering.

The 75 Curlon/25 Poly sample exhibits good thermal efficiencies before and after laundering, good flammability properties before and after laundering, good compression recovery, good dimensional stability and good durability to laundering. However, the sample demonstrates poor water repellent characteristics as it absorbs alot of water. Based on conversations with Dr. Novis Smith of RK Carbon Fibers, Inc., a fluorocarbon water repellent finish is now being applied to Curlon. The batting tested exhibited a heavier weight than desired and it is possible to reduce the weight by using a smaller denier fiber. More work is needed in this area.

The 60% Poly/40% EDF sample, although blended very poorly,

exhibited good thermal properties before laundering. However, it offered no significant improvement over the std Nomex batting after laundering and exhibits a considerable loss of thickness in laundering which would effect the long-term performance of an item. This sample exhibits unsatisfactory flammability characteristics after laundering and unsatisfactory water repellent characteristics. This sample does not merit further investigation.

The fiberglass batting samples exhibit satisfactory water absorption rates after 20 minutes, good flammability characteristics, and satisfactory compression properties. (Although the fiberglass fibers may break after repeated compression testing - further work in this area would need to be conducted). The Acoustic AA batt exhibits the same thermal efficiency as down. The Microlite AA and Acoustic AA samples exhibit comparable thermal efficiencies (clo/oz/sq yd) to the other insulations evaluated. Laundered samples were not tested as these samples are not being recommended for use in clothing items due to skin irritation typically associated with fiberglass battings and unsatisfactory durability based on past performance. [24,25]

The modacrylic battings were tested as received (quilted), and exhibited no significant improvements over the std. Nomex batting before or after laundering and demonstrated unsatisfactory durability to laundering. No further testing was conducted on these samples.

Recommendations:

1) Prototype testing should be conducted on the P84/poly and 75 Curlon/25 Poly samples to determine their performance properties (thermal, compression, laundering durability, flammability, etc.) before and after laundering when constructed into a garment and tested on a thermal mannikin.

2) More extensive flammability testing should be conducted to determine if a more suitable test method exists, and to study the effect of density and synergistic effects on FR/non FR blended batts.

3) Development of a Curlon blend in a lower weight range should be explored as finer denier Curlon fibers are available. An experimental SP5 (special precursor 5) which is approximately 0.5 denier, has been made but further development is needed in this area. It is estimated a SP5 could reduce the batting weight by 25-35%. An SP8 (7.5 microns) is available which could reduce the batting weight by 15-20%.

This document reports research undertaken at the U.S. Army Soldier Systems Command, Natick Research, Development and Engineering Center and has been assigned No. NRDEC/TR-96/033 in the series of reports approved for publication.

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APPENDICES

Appendix A
Tables A-1 - A-7

Table A-1 : Guarded Hot Plate Testing - Batting Samples (Unquilted)

Material	Thickness (in) 0.002 psi	Bulk Density (lb/cu ft)	Weight (oz/sq yd)	Clo Intrinsic	Clo/ oz/sq yd	Clo/in.
Nomex	(unquilted)					
Unlaundered*	0.29	1.28	4.46	1.34	0.3	4.62
Laundered*	0.23	1.36	3.65	1.11	0.3	4.83
Nomex (QR)	(quilting removed)					
Unlaundered	0.27	1.31	4.25	1.33	0.31	4.93
Laundered	0.2	1.82	4.35	1.12	0.26	5.6
P84/Poly						
Unlaundered	0.89	0.35	3.71	3.63	0.98	4.08
Laundered	0.5	0.62	3.73	2.42	0.65	4.84
60% Poly/40% EDF						
Unlaundered	0.59	0.59	4.17	2.61	0.63	4.42
Laundered	0.26	1.42	4.37	1.1	0.25	4.23
75% Curlon/ 25% Poly	(quilting removed)					
(QR) Unlaundered	0.88	0.67	7.03	4.41	0.63	5.01
Laundered*	0.58	0.99	6.87	3.13	0.46	5.4

Data average of 3 samples unless otherwise specified
*Data average of 2 samples

Table A-2: Rapid K Testing - Thermal Conductivity vs. Density

	original			0.5 lb/cu ft		1.0 lb/cu ft		1.5 lb/cu ft		2.0 lb/cu ft	
Material	Density	Thickness	Clo	Thickness	Clo	Thickness	Clo	Thickness	Clo	Thickness	Clo
Nomex	(quilting removed)										
Unlaundered ***	1.52	0.24	1.17					**0.23	1.16	0.18	0.94
Laundered*	1.74	0.2	1.02							0.17	0.89
P84/Poly											
Unlaundered ***	0.36	0.85	3.07	0.62	2.49	0.31	1.51	0.2	1.09	0.15	0.88
Laundered **	0.57	0.55	2.32			0.31	1.53	0.21	1.12	0.16	0.91
60% Poly/40% EDF											
Unlaundered *	0.58	0.61	2.55			0.36	1.71	0.23	1.25	0.18	1.03
Laundered *	1.53	0.26	1.27							0.2	1.03
75% Curlon/ 25% Poly	(quilting removed)										
Unlaundered *	0.65	0.9	4.04			0.59	2.87	0.39	2.06	0.29	1.6
Laundered *	0.96	0.6	2.94			0.57	2.84	0.38	2	0.29	1.55
Microlite AA (Fiberglass)											
Unlaundered ***	0.57	1.03	4.63			0.58	2.95	0.39	2.11	0.29	1.67
Laundered											
Acoustic AA (Fiberglass)											
Unlaundered ***	0.4	0.9	3.57	0.72	3.11	0.36	1.84	0.24	1.37	0.18	1.06
Laundered											

* Average of 3 samples

** Average of 4 samples

***Average of 6 samples

Table A-3: Flammability Testing								
Material	After Flame (secs)		After Glow (secs)		Char lenght (in)		Affected Area (in)	Comments
	Range	Average	Range	Average	Range	Average	Range	
Nomex (QR)								
Unlaundered								
Machine	0	0	4.0 - 11.0	8	0.63 - 1.38	0.98	1.63 - 2.0	Initially sample shrinks from flame then catches fire.
Cross- Machine	0	0	8.0 -12.0	10.8	1.5 - 2.13	1.68	2.13 - 2.38	Flame travels 8 - 9 secs then goes out on laundered samples.
Laundered								
Machine *	0	0	5.0 - 11.0	8.13	0.88 - 2.75	1.6	1.63 -3.5	
Cross- Machine	0	0	8.0 - 16.5	11.6	0.88 - 2.25	1.6	2.25 -3.38	
P84/Poly								
Unlaundered								
Machine**	0	0	0.0 -1.0	0.11	0.25 - 0.63	0.49	2.25 - 3.75	Sample shrinks from flame (like Nomex) them flame spreads.
**	11.5		2		1.25		8.25	In some cases char lenghth is shrunken fiber length.
Cross- Machine								
Laundered								
Machine	0.0-24.4	11.4	0	0	0.5 -4.25	1.88	4.25 - 12.0 (TC)	In samples totally consumed (TC) - top area continues to burn
Cross - Machine**	0	0	0	0	0.38 - 1.38	0.88	1.88 - 2.0	after flame reaches top causing top area to shrink away.
**	43.2		0		0.75		12.0 (TC)	
60% Poly/40% EDF								
Unlaundered								
Machine	0	0	0	0	0.0 - 0.63	0.28	0.75 - 2.13	Fibers burn but no noticeable flame spread more like an aftergow
Cross - Machine	0	0	0	0	0.63 - 1.13	0.53	0.88 - 2.5	effect.
Laundered								
Machine	16.1 - 54.1	28.3	0 - 4.0	2.2	4.88 - 10.63	6.6	6.75 - 12.0 (TC)	Samples very brittle after testing. Sometimes flame would
Cross - Machine*	21.0 - 78.5	52.9	0 - 4.0	2	2.88 - 12.0 (TC	8.38	8.63 - 12.0 (TC)	to go out then reappear and burn sample
75% Curlon/ 25% Poly (QR)								
Unlaundered								
Machine	0	0	0	0	0	0	0	When flame hits sample, fibers in direct contact with flame glow.
Cross - Machine	0	0	0	0	0	0		No flame spread. When flame removed no burning visible.
Laundered								Slight dicoloration of fibers exposed to flame.
Machine	0	0	0	0	0	0		No visible char lenght (black fiber).
Cross - Machine	0	0	0	0	0	0		
Microlite AA								
Unlaundered								
Machine	0	0	0	0	0	0	0.13 -1.88	Some discoloration (browning) in charred area. Also some residue in charred area.
Cross - Machine	0	0	0	0	0	0	0.38 - 2.75	
Acoustic AA	(fiberglass with polyester scrim)							
Unlaundered								
Machine	0	0	0	0	0 - 1.0	0.48	0 - 0.63	
Cross - Machine								
Program Target		0		25 (max)		3.5 (max)		No flame propagation, melting or dripping.

Average of 5 samples unless otherwise specified

*Average of 4 samples

**Data on one sample in group - not averaged into total .

Table A-4: Compression Properties

Material	Compressional Recovery (%)	Compressibilty (%)	Resilience (%)
Requirement (MIL-B-81813)	75 (min)		
Nomex (QR)			
Unlaundered	85.1	92.6	83.9
Laundered	88.6	89.5	87.2
P84/Poly			
Unlaundered	89.1	98.2	90.2
Laundered	91	96.4	90.6
60% Poly/40% EDF			
Unlaundered	89.6	94.9	89.1
Laundered	87.6	86	85.6
75% Curlon/ 25% Poly (QR)			
Unlaundered	95.3	89.8	94.8
Laundered*	92.9	87.9	91.9
Microlite AA			
Unlaundered	87.3	95	86.6
Acoustic AA			
Unlaundered	77.8	97.1	77.1

Average of 6 samples unless otherwise specified.

* Average of 5 samples

Table A-5: Absorptive Capacity and Wet Loft Retention After 20 Minute Immersion

	Original		After 20 Min.		Absorptive Capacity	Loft Retention
	Thickness 0.1 psi (in.)	Weight (gms)	Thickness 0.1 psi (in.)	Weight (gms)	(%)	(%)
Program Target					150 (max)	95(min)
Nomex (QR)						
Unlaundered	0.143	0.77	0.1	17.1	2183.9	70.3
Laundered	0.093	0.83	0.08	13.4	1626	86.6
P84/Poly						
Unlaundered	0.106	0.77	0.01	0.88	115	95.4
Laundered	0.1	0.68	0.093	0.82	119.3	93.3
60% Poly/40% EDF						
Unlaundered	0.24	0.9	0.221	19.62	2169.6	92.8
Laundered	0.11	0.82	0.104	1.5	184.6	93.3
75% Curlon/25% Poly						
Unlaundered	0.214	1.3	0.192	19.62	1534.1	89.3
Laundered	0.183	1.2	0.151	26.8	1984.3	83.3
Microlite AA						
Unlaundered	0.36	1.3	0.343	1.9	156.52	95.6
Acoustic AA						
Unlaundered	0.2	0.9	0.205	1.4	158.9	96.1

Average of 6 samples

Table A-6: Launderability

Material	Dimensional Stability		Laundering Durability	Comments
	Warp	Filling	Rating	
Nomex (DQ)	2.5	1.8	4.5	Some hairiness on back of batting
P84/Poly (SQ)	1.9	2.9	5	
60% Poly/40% EDF				No roping of fibers but wrinkling/ puckering of batting may be a result of poor blending and opening of fibers.
(DQ)	2.7	0.9	4.5	
(SQ)	2.4	2.4		
75% Curlon/25% Poly* (DQ)	2.4	1.6	4.5	
Modacrylic				
2.5" Squares	0.8	2.6	3	Some very thin areas - little if any insulation
4" Squares	0.6	2.1	3	Thick and thin spots

Average of 3 samples unless indicated otherwise.
*Average of 2 samples
DQ - Dumbell Quilted
SQ - Straight (6") Channel Quilting

Table A-7: Guarded Hot Plate Testing - Quilted Panels

Material	Thickness 0.002 psi	Bulk Density (lb/cu ft)	Weight (oz/sq yd)	Clo Intrinsic	Clo/ 0z/sq yd
Nomex	nomex shell - dumbell quilted				
Unlaundered	0.34	2.65	10.63	1.33	0.13
Laundered	0.27	3.36	10.86	1.13	0.1
P84/poly blend	nylon shell - straight channel quilt				
Unlaundered					
Laundered	0.53	1.27	8.15	2.28	0.28
60% Poly/40% EDF	nylon shell - straight channel quilt				
Unlaundered					
Laundered	0.34	2.09	8.45	1.38	0.16
	FR cotton shell - dumbell quilted				
Unlaundered	0.58	2.48	17.36	2	0.12
Laundered	0.41	3.63	17.85	1.55	0.09
75% Curlon/ 25% Poly	nomex shell - dumbell quilted				
Unlaundered	0.66	1.7	13.41	2.78	0.21
Laundered*	0.62	1.9	14	2.87	0.21
Modacrylic Battings	1 layer FR Cotton - 2.5 inch squares (4.5 oz/sq yd batting)				
Unlaundered	0.41	1.98	9.68	1.2	0.12
Laundered	0.14	6.02	9.87	0.61	0.06
	1 layer FR Cotton - 4.0 inch squares (8.2 oz/sq yd batting)				
Unlaundered	0.62	2.38	15.28	1.62	0.11
Laundered	0.22	5.7	15.02	0.93	0.06

Average of 3 samples unless otherwise specified
* Average of 2 samples

APPENDIX B - Product Information Sheet: Fiberglass Battings

MvL
Manville

High Performance Insulations

Microlite® AA Blankets

Aircraft Acoustical and Thermal Insulation

Microlite AA Blankets are lightweight, flexible, thermal and acoustical insulating materials designed for use where space and weight savings are a critical consideration.

Applications. Formed from resin bonded borosilicate glass fibers, Microlite AA Blankets provide optimum thermal and acoustical insulating performance for applications up to 450°F. These blankets help control thermal and acoustical transmission in a variety of aerospace applications, and are particularly well suited for insulating the fuselage wall cavities of commercial and private aircraft.

Advantages. Microlite AA Blankets offer superior acoustic and thermal performance per unit weight of insulation used. AA blankets are phenolic bonded, non-combustible, and easily meet the most stringent smoke density, smoke toxicity and total heat release standards.

Because Microlite AA Blankets are non-cellular and moisture-resistant, they will not support biological growth or vermin. They also provide excellent stability with age—the exceptional resiliency of the glass fibers prevents vibrational settling and retains their excellent sound attenuation and thermal properties.

Available Forms. Microlite AA Blankets are furnished with a water repellent thermosetting phenolic binder which provides flame resistance, anti-punk, and excellent dimensional stability. An additive is used to provide water repellency to the cured blanket for service in areas where high altitude moisture condensation may occur. In circumstances where moisture is not a concern, plain *phenolic* can be specified.

Type: Flexible Blanket

Temperature Limit: 450°F (232°C)

Applications:

- Aerospace
- Fuselage Wall Cavities of Aircraft

Insulation Properties:

- High Sound Absorption
- Moisture Resistant
- Low Heat Transfer
- Noncombustible
- Excellent Dimensional Stability
- Continuing High Performance
- Exceptionally Low Smoke and Toxicity

Microlite® AA Blankets

Aircraft Acoustical and Thermal Insulation

Specifications

Thermal Conductivity (BTU-In.)/(Sq. Ft.-Hr.-°F) (ASTM C-518)

	Mean Temp. °F (between hot surface and cold surface)					
Density (lbs./cu. ft.)	50°	75°	100°	200°	300°	400°
.4	.25	.28	.30	.38	.47	.64
.6	.24	.25	.27	.35	.42	.55
1.5	.21	.22	.23	.28	.32	.38

Thermal Conductivity (Watt/Meter-°C) (ASTM C-518)

	Mean Temp. °C (between hot surface and cold surface)					
Density (kg/m^3)	10°	24°	38°	93°	149°	204°
6.4	.036	.040	.043	.055	.068	.092
9.6	.035	.036	.039	.051	.061	.079
24.0	.030	.032	.033	.040	.046	.055

Acoustical Performance (ASTM C-423, Type A Mounting)

Sound Absorption Coefficients

Density x Thickness	Frequency (Hz)						
(lbs./cu./ft.) x (inches)	125	250	500	1000	2000	4000	NRC
0.4 PCF x 1 inch (6.4kg/m³ x 25mm)	.02	.06	.32	.73	.93	.96	.50
0.6 PCF x 1 inch 9.6kg/m³ x 25mm)	.03	.14	.55	.92	.99	1.01	.65
1.5 PCF x .375 inch (24kg/m³ x 9.5mm)	.03	.05	.22	.81	1.02	.99	.50

Acoustical Performance (ASTM C-423-66, No. 6 Mounting)

Sound Absorption Coefficients

Density x Thickness		Frequency (Hz)						
(lbs./cu./ft.) x (inches)		125	250	500	1000	2000	4000	NRC
.4	1	.18	.39	.37	.72	.95	.99	.60
.6	1	.18	.41	.50	.92	.99	.96	.70
1.0	1	.20	.42	.52	.99	.98	.95	.75
1.5	.375	.16	.36	.23	.57	.96	.90	.55

Sound Attenuation (ASTM E-90 Sound Transmission Loss)

	Sound Loss (in decibels per inch)				
Density x Thickness	Frequency (Hz)				
(lbs./cu./ft.) x (inches)	250	500	1000	2000	4000
0.4 PCF x 1 inch (6.4 kg/m³ x 25 mm)	0.83	1.5	3.5	6.2	9.6
0.6 PCF x 1 inch (9.6 kg/m³ x 25 mm)	0.96	2.2	4.5	7.0	9.9
1.5 PCF x .375 inch (24 kg/m³ x 25 mm)	3.4	3.7	8.3	18	24

Compliance with Government & External Specs: ASTM C-800 (replacing MIL-B-5924), BMS 8-48, DMS 2151, DMS 1967, STM 26-701, LAC C26-1277, C-26-1184, ATS 1000.001, FAR 25.853 and 25.855, OSU 65/65.

The Type A mounting is considered to yield more accurate and reproducible test data than the previously specified No. 6 mounting and may be more representative of end-use acoustical performance in aircraft. No. 6 mounting coefficients are given solely for comparison and conversion of specifications.

The physical and chemical properties of Manville Microlite AA Blankets represent typical, average values obtained in accordance with accepted test methods and are subject to normal manufacturing variations. The data is supplied as a technical service and is subject to change without notice. Check with your Manville regional office to obtain current information.

For information on other Manville High Performance Insulation Products, write to Manville High Performance Insulations or call: 1-800-654-3103 (in Colorado call: 303-978-4900).

MvL Manville

High Performance Insulations

P.O. Box 5108
Denver, Colorado 80217

Regional Sales Offices:

Defiance, Ohio
1-800-334-7451 (inside Ohio)
1-800-334-2399 (outside Ohio)

Cleburne, Texas
1-800-722-8027 (inside Texas)
1-800-221-9018 (outside Texas)

Corona, California
1-800-367-6955

Canada
(416) 626-5200

APPENDIX C - Data on Additional Battings Tested

Guarded Hot Plate Testing						
Material	Thickness (in) 0.002 psi	Bulk Density (lb/cu ft)	Weight (oz/sq yd)	Clo Intrinsic	Clo/ oz/sq yd	Clo/in.
Batting (Unquilted)						
Pyroloft A						
Unlaundered	0.66	0.42	3.31	4.21	1.27	6.38
Laundered	0.45	0.64	3.47	2.72	0.78	6.04
	Satisfactory durability in laundering.					
Pyroloft C						
Unlaundered	0.39	0.34	1.6	1.89	1.18	4.85
Laundered	0.23	0.59	1.63	1.02	0.63	4.43
	Unsatisfactory durability in laundering.					
Pyroloft CA						
Unlaundered	0.86	0.73	7.4	3.41	0.46	3.97
Laundered	0.69	0.97	8.05	2.99	0.37	4.33
	Good durability in laundering.					
72% Curlon/28% Poly						
Unlaundered	0.17	1.87	3.82	1	0.26	5.88
Laundered						
	Problems with opening of polyester.					
Quilted Panels						
Pyroloft A						
Unlaundered						
Laundered	0.48	1.38	7.85	2.41	0.31	5.02
Pyroloft C						
Unlaundered						
Laundered*	0.29	1.91	6.66	1.14	0.17	3.93
Pyroloft CA						
Unlaundered						
Laundered	0.75	1.39	12.47	3.04	0.24	4.05
Average of 2 samples unless specified otherwise.						
* One sample only						

Flammability					
Material	After Flame (secs)	After Glow (secs)	Char lenght (in)	Affected Area (in)	Comments
Pyroloft A *					
Unlaundered					
Machine					
	0	1	0	4	
	0	1.5	0.25	3	
Average	0	1.5	0.13	3.5	Stops glowing and flaming
Cross Machine	0	1	0.75	3.5	when flame is removed.
	0	0	0.63	2.5	
Average	0	0.5	0.69	3	
Pyroloft C*					
Unlaundered					
Machine	0	1	0.06	4	
	0	1	0.06	2.75	Burns in area where
Average	0	1	0.06	3.38	exposed to flame only.
Cross Machine	0	<1.0	0.63	2.63	
	0	<1.0	0.5	3	
Average	0	<1.0	0.57	2.82	
Pyroloft CA*					
Unlaundered					
Machine	0	2	0.19	3	
	0		0.06	5	
Average	0	2	0.13	4	
Cross Machine	0	1	0.5	3.25	
	0	1	0.5	3.06	
Average	0	1	0.5	3.16	
72% Curlon/28% Poly					
Unlaundered					
Machine	0	2.5	0	0	
	0	>30	0	0	
	0	20	0	0	
	0	2	0	0	
Average	0	13.63	0	0	Poor opening of polyester
Cross Machine	0	0	0	0	seems to attribute to
	0	0.5	0	0	after glow times.
	0	1.5	0	0	
	0	16	0	0	
Average	0	4.5	0	0	
*Tested without Scrim					

Appendix D - Flammability Testing on Individual Specimens

Vertical Flammability Testing						
Material		Direction	AF	AG	Char Length	Affected Area
			(sec)	(sec)	(in.)	(in.)
Nomex						
(Data from files)	Unlaundered	Machine	0	9	2.9	
		Cross Machine	0	18	3	
Nomex	Unlaundered					
(Current testing)		Machine	0	11	0.63	2
			0	6	1	1.75
			0	8	1.38	1.75
			0	11	1.13	2
			0	4	0.75	1.63
		Average	0	8	0.98	
		Cross Machine	0	12	1.63	2.38
			0	8	1.75	2.13
			0	8	1.5	2.25
			0	14	1.38	2.13
			0	12	2.13	2.75
		Average	0	10.8	1.68	
	Laundered					
		Machine	0	11	2.75	3.5
			0	8	1.13	3
			0	8.5	0.88	1.63
			0	5	1.63	3.13
		Average	0	8.13	1.6	
		Cross Machine	0	8	1.13	2.25
			0	11	1.75	2.75
			0	16.5	2.25	3.38
			0	12.5	0.88	2.25
			0	10	2	2.5
		Average	0	11.6	1.6	

Vertical Flammability Testing						
Material		Direction	AF	AG	Char Length	Affected Area
			(sec)	(sec)	(in.)	(in.)
82% P84/ 18% Poly	Unlaundered	Machine	0	0	0.5	2.25
			0	1	0.75	2.5
			0	0	0.75	3.75
			0	0	0.63	3.75
			*11.5	*2	*1.25	*8.25
			0	0	0.38	3.5
			0	0	0.38	3
			0	0	0.38	3
			0	0	0.38	2.63
			0	0	0.25	3.75
		Average	0	0.11	0.49	
		Cross Machine	0	0	0.38	1.75
			0	0	0.75	4
			0	0	0.38	2
			0	0	0.38	1.38
			0	0	0.38	1.5
		Average	0	0	0.45	
	Laundered	Machine	22.2	0	1	12.0 (TC)
			4.1	0	2.5	5.63
			0	0	0.5	3.5
			24.4	0	4.25	12.0 (TC)
			6.3	0	1.13	4.25
		Average	11.4	0	1.88	
		Cross Machine	0	0	0.63	1.88
			0	0	0.38	2
			*43.2	*0	*0.75	*12.0 (TC)
			0	0	1.13	2.5
			0	0	1.38	2
		Average	0	0	0.88	
* Data excluded from average						
TC - totally consummed						

Vertical Flammability Testing						
Material		Direction	AF	AG	Char Length	Affected Area
			(sec)	(sec)	(in.)	(in.)
60% Poly/40% EDF	Unlaundered	Machine	0	0	0	0.75
			0	0	0.38	1.13
			0	0	0.38	1.25
			0	0	0	1.5
			0	0	0.63	2.13
		Average	0	0	0.28	
		Cross Machine	0	0	0	1.13
			0	0	0.88	2.38
			0	0	0.63	0.88
			0	0	0	0.88
			0	0	1.13	2.5
		Average	0	0	0.53	
	Laundered	Machine	21	4	8.5	8.5
			28.4	3	10.63	10.63
			16.1	2	4.88	6.75
			21.9	0	6.25	10.13
			54.1**	4 / 2	2.75	12.0 (TC)
		Average	28.3	2.2	6.6	
		Cross Machine	59.6	1	12	12.0 (TC)
			52.5**	3	12	12.0 (TC)
			21	0	6.75	8.63
			78.5	4	2.88	12.0 (TC)
		Average	52.9	2	8.38	
** Sample went out and reflamed again						
TC - totally consumed						

Vertical Flammability Testing						
Material		Direction	AF	AG	Char Length	Affected Area
			(sec)	(sec)	(in.)	(in.)
75% Curlon/ 25% Poly	Unlaundered	Machine	0	0	0	****
			0	0	0	
			0	0	0	
			0	0	0	
			0	0	0	
		Average	0	0	0	
		Cross Machine	0	0	0	
			0	0	0	
			0	0	0	
			0	0	0	
	Laundered		0	0	0	
		Average	0	0	0	
		Machine	0	0	0	
			0	0	0	
			0	0	0	
			0	0	0	
			0	0	0	
		Average	0	0	0	
		Cross Machine	0	0	0	
			0	0	0	
			0	0	0	
			0	0	0	
			0	0	0	
		Average	0	0	0	
****Black fiber - difficult to determine affected area- appears to be little if any area affected.						

Vertical Flammability Testing						
		Direction	AF (sec)	AG (sec)	Char Length (in.)	Affected Area (in.) (most affected area)
Fiberglass Battings						
Microlite AA	Unlaundered	Machine	0	0	0	1.88 (0.88)
			0	0	0	0.63 (0.13)
			0	0	0	1.0 (0.38)
			0	0	0	1.88 (0.63)
			0	0	0	1.75 (0.5)
		Average	0	0	0	
		Cross Machine	0	0	0	1.75 (1.0)
			0	0	0	0.63 (0.38)
			0	0	0	1.5 (0.38)
			0	0	0	2.13 (0.75)
			0	0	0	2.75 (1.5)
		Average	0	0	0	
Acoustic AA	Unlaundered	Machine			scrim batting	
(polyester scrim			0	0	5.0 4.13	6.5 (4.5)
burns)			0	0	2.88 2.5	3.63 (0.75)
			0	0	2.88 0.38	2.13 (1.13)
			0	0	1.13 1.0	1.0 (0.63)
			0	0	4.5 0.75	6.0 (4.5)
			0	0		
		Average	0	0	1.88 0.5	4.38 (0.88)
		Cross Machine	0	0	1.63 0.63	3.0 (1.0)
			0	0	0 0	0.88 (0.88)
			0	0	1.0 0.25	1.88(1.0)
			0	0	2.88 0.5	3.25 (0.75)
		Average	0	0		